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*BIOLOGICAL BASES
OF THE
EVOLUTION OF MUSIC*



By I. I. KRYZHANOVSKY

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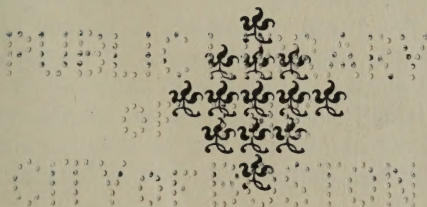
The

Biological Bases of the
Evolution of Music

By IVAN IVANOVICH KRYZHANOVSKY

Translated from the
Author's unpublished Manuscript

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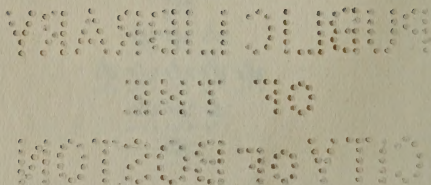
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BIOGRAPHICAL NOTE

THE author of *The Biological Bases of the Evolution of Music* was peculiarly qualified to write on the subject, inasmuch as he had a scientific as well as a musical training.

Born at Kiev in 1867, he studied the violin and musical theory at the Kiev School of Music, and medicine at St. Vladimir's University. He became house surgeon at a clinic, but in 1896 abandoned the medical profession and entered Rimsky-Korsakov's class at the St. Petersburg Conservatoire. Material circumstances, however, compelled him to return to his former calling, and he took up an appointment as prosector at the St. Petersburg Medical Institute; he also worked for two years in I. P. Pavlov's physiological laboratory. In 1914 he went to the front as senior medical officer of a Red Cross hospital, was taken prisoner at Lodz and remained in captivity until 1917. During this period, and until 1921, he devoted himself to composition, and wrote his symphonic works, a quartet, a pianoforte trio, and a pianoforte concerto. He produced fifty opus numbers, of which less than half have been published.

In addition to his musical activities, Kryzhanovsky was the author of *A Natural System of Playing and Professional Ailments of the Hands*, *The Physiological Bases of Pianoforte Technique*, and *The Biological Bases of the Evolution of Music*. The last-named provided the subject for a course of lectures at the Institute of the History of the Arts. Kryzhanovsky also lectured on the physiology of playing at the Leningrad Conservatoire, and presented communiqués on this question to the Physiological Society, the Surgical Society, and the Neuropathologists' Conference.

A composer and a violinist, throughout his life music was Kryzhanovsky's first love, but pressure of circumstances and the cares of a family prevented the full development of his artistic talents, which also found expression in painting. In a letter to

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V. M. Belaiev, written shortly before his death, he says: 'In May 1925 I shall celebrate the twenty-fifth anniversary of my activities as a musician and a teacher. I cannot picture to myself my musical physiognomy, as I have heard *hardly any* of my works performed. Perpetually straitened circumstances and family cares have prevented the complete development of my talent (admitting that I am possessed of such), and the future is gloomy and full of uncertainty.'

The troubles of existence did not, however, damp his enthusiasm for new things in music, of which he was an ardent propagandist. This enthusiasm had a somewhat injurious effect on his own compositions, which are often so much influenced by others as to lose their individuality. But when he succeeds in freeing himself from such influences and speaks in his own tongue, his music, without being strikingly novel, attracts one by its frankness and sincerity and the tinge of sadness with which it is permeated. He is at his best in his writing for strings and the voice.

Kryzhanovsky died of heart disease in December 1924.

(For the foregoing the translator is indebted to articles by Kryzhanovsky himself, V. Yakovlev, and Julia Weissberg, published in Nos. 13 and 14 of *Sovremennaya Muzyka*.)

THE BIOLOGICAL BASES OF THE EVOLUTION OF MUSIC

THE purpose of this essay is to familiarize the reader with the fundamental principles that enable us to determine the essential nature of the evolution of music, and to show that it is subject to, and accomplished in accordance with, the biological laws governing the evolution of living things.

If these laws, obeyed by the whole of animated nature, comprise all the basic elements of life in its every aspect, it seems quite natural that we should aspire to extend their application as far as possible, and to include within their scope the evolution of music, as one of the manifestations of vital creative energy.

We are, of course, confronted with an intricate problem. We have to work in the extremely complex realm of an art in which there are many occult or, shall we say, mysterious elements, an art that is supremely free and gives us a perfect reflection of the most delicate movements of the creative spirit. On the other hand, we come into contact with the domain of science and exact scientific laws.

At the outset we are faced with a series of questions. Can we find in music objective, law-conforming data which would enable us to approximate these two realms of biology and music, apparently so entirely foreign to one another? Can we discover in musical productions any data susceptible of accurate measurement, or any of the exact signs which distinguish one musical work from another? Is it possible to estimate

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any musical work from an absolutely objective point of view? Is it to be expected that the capricious play of the creative spirit can be crystallized into regular forms, subjected to some rigid system of rules? And if this system is discoverable within the limits of a single musical work, is it to be anticipated that the study of a series of works will make it possible to establish a strictly logical sequence in the development of music during more protracted periods?

Before answering these questions and determining precisely what the essential nature of the evolution of music consists of, let us try briefly to characterize music as an art.

If it be true that 'life is movement', then music presents itself as a supremely real and living art, since in movement alone is it recognized. Connected only with the flow of sound, as the immediate embodiment of the soul's experiences music has no symbol in the external world—it reflects nothing save that which is engendered in the soul of its creator. The creative spirit incarnates in music its transient moods and its more profound experiences; and it acts upon the hearer by evoking in him moods and experiences parallel to his own. Nevertheless it is quite clear that the inner content of a musical production—that which it tells in its own language—is extremely difficult to define, especially when the music is not combined with words or connected with a definite programme. As we know, attempts to associate music with external forms or with explicit spiritual experiences are often based on very unsure foundations. It is by no means easy

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to estimate the objective value of the musical content. We judge it in accordance with the impression which it makes upon us. It is well known, however, that to a listener, a given musical work heard several times may assume a different aspect on each occasion. It is not at all surprising that the impressions produced upon the bulk of an audience that has sat through a performance of a Beethoven symphony will vary enormously, both in power—ranging from utter indifference to the deepest feeling—and in character. So if we took into consideration the inner content of music, the possibility would be entirely excluded of objectively appraising any musical production, and of discovering in it any data accessible to exact measurement and comparison.

But it will be quite a different matter if we ignore the expressive side of music and confine ourselves exclusively to its sound-material.

We recall Leibnitz's phrase, 'Music is the unconscious delight of mathematics,' and shall try to determine the relation of music to mathematics. Whatever the inner content of a musical work, on the external side we have to do with a greater or lesser mass of sounds—a mass which can be measured, since sound is nothing more than a rigidly defined number of vibrations set up by the sounding body and transmitted through the medium of the air. Taking into consideration only the mathematical correlations of the sounds, only the figures which express the number of vibrations of the notes composing a given work, we can obtain objective data unquestionably characteristic

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of any work; and by comparing a series of such data we can contrast one musical production with another, and the productions of one period with those of another. So that it would seem possible to present any musical composition in the guise of a mathematical formula or of a complex geometrical figure, disregarding entirely its emotional content and the composer's moods and experiences as incapable of exact analysis. In this way the problem of investigating the evolution of music would be enormously simplified—to prepare the mathematical formulae, to draw the diagrams of musical productions and then analyse them would suffice. Unfortunately this apparently most accurate method cannot at present be applied, since we have not discovered how to compare and combine the relations obtained between the numbers of the vibrations of the sounds comprising a musical production in a form which would give us the formulae distinctly characteristic of that production.

Be that as it may, we have still one way out—we must rely on the external bases of a musical work, analyse them, make use of the mathematical correlations. And if we find it impossible to grasp the exact mathematical correlation of all the sounds of the given work and to reduce them to a single formula, it remains for us to employ only the most characteristic relations. These simplest mathematical correlations will enable us to discuss the question of consonance and dissonance—a question which, as we shall presently show, proves to be the axis of the whole evolutionary movement of music.

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Let us turn to the reception of music by each of us individually, to our impressions, and to the value which we set upon musical productions. We shall have to admit that we are guided solely by our sympathies in accepting or rejecting any work or the entire musical output of a composer. We may have studied theory and composition, we may be ignorant of them—it makes no essential difference. In the former case we shall merely be able to discuss in fuller detail the merits and defects of a composition. In both cases the difference will be similar to that between a chemist giving his opinion of, let us say, a wine on an analytical basis and an experienced taster whose verdict depends on his palate. Broadly speaking, we can say on hearing a musical work that we do or do not like it, that it impresses us or leaves us cold, that it does or does not grip us—this is all we can say without entering into an exact analysis of the work. This opinion will be the result of our unconscious enjoyment of the music. The phenomena of resonance are, of course, familiar to us. Any string, metal plate, &c., capable of emitting notes with a definite number of vibrations is accompanied in vibration by sound waves of air, which are excited by the note having the same number of vibrations. The mass of the audience in a concert-hall may be likened to a complex system of variously tuned plates or strings. Vibrations in these strings will only be excited by the note to which each individual hearer is tuned. In this mass the more similarly tuned elements there are, the more will a given musical work resonate and excite sympathetic vibrations or, conversely, leave the audience

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absolutely cold, neither reacting nor resonating to the music.

In the first instance the hearer receives a pleasant or unpleasant impression, according to the character and strength of the vibrations; in the second he remains entirely indifferent.

The whole of the various impressions received may be arranged in a certain gradation between the two extreme points—at the one end enjoyment, at the other irritation and a disagreeable sensation. If we try to concentrate and express in one word each of these poles, at which, as at the focus of a convexo-convex lens, all the rays of sound reception intersect, we shall not find better terms than consonance and dissonance. Everything that is consonant produces a pleasant effect on our ear; everything that is dissonant arouses an unpleasant feeling.

In musical theory, with the concept of consonance and dissonance is connected a definite mathematical correlation between the numbers of the vibrations of the notes forming a consonance and a dissonance. The more consonances there are in music, the more agreeable the sensations which it should evoke in us, sensations leading by a certain gradation to complete tranquillity and bringing repose to the soul of the hearer. The more dissonances there are in music, the more it agitates us; in extreme cases it even produces a state of exasperation. Probably we have often been obliged to listen to music concerning which we have indignantly exclaimed: 'Why, bless me, it's nothing but dissonances!'

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Though we may be absolutely ignorant of the theory of music, every one of us applies the terms consonance and dissonance so often that we have become accustomed to them and connect with them perfectly definite conceptions. If we could accurately analyse our impressions and were acquainted with the theory of music, we should certainly notice that consonance and dissonance were by no means as constant as we imagined them to be. Looking back at our individual development, our ontogenesis, over a longer or shorter period, we should see that many of our former dissonances have been transformed into consonances; that many things which had unpleasantly astonished us in compositions new to us, on a further hearing lost their pungency and became quite ordinary to our ear. That which has happened with each of us during his life also runs like a red line through the whole history of music, its phylogenesis. An investigation of longer or shorter periods in the development of music will show us that the conception of consonance and dissonance in the course of time undergoes a gradual change. As the evolution of music is intimately connected with the variability of the contents of these two concepts, we must pause to consider them and enter into a theoretical explanation.

All musical sounds are distinguished by the regular periodicity of their vibrations—of these sounds we can single out a vast number of varying pitch, according to the number of vibrations of the sounding body. We cannot, however, hear all the sounds but only those which are included within definite limits. If the

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sounding body—a string, a tube—produces less than 16 vibrations per second, we shall not perceive a sound, but merely detached impulses of the air. Nor can we hear sounds whose vibrations are more than 40,000–50,000 per second. All the musical sounds within these limits are perceptible to us, however slight the difference between them. For example, we can distinguish a note with 1,000 vibrations from one with 1,000·5 vibrations. If we take as the fundamental note the A of the tuning-fork with 435 vibrations, the nearest distinguishable notes below and above it will have 434·4 and 435·6 vibrations respectively. Thus within the interval of an octave on the piano it is possible to insert 1,200 distinguishable notes. We have all heard the gradual raising of the pitch during the tuning of a string, which of course includes all these transitions, each representing one-tenth part of a vibration. If we wanted to use in our music all the notes audible to our ear, we should get a vast number of them, far exceeding the modest limits of those with which we are at present satisfied. The reduction of such a mass of notes to definite relations comprehensible by us is beyond our powers. For our music we select certain series in which the distance between two adjacent notes is equal to a semitone. Hence the distance of the octave is divided not into 1,200 notes but only into 12. The ratio of the two notes forming a semitone is equivalent to $15/16$, consequently the octave consists of 12 semitones. Every succeeding octave above will have double the number of vibrations for each of its notes, i.e. the relation between any note

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of a given octave and the note of the same name in the octave above is expressed by the ratio 1 : 2. Our piano has 85-88 keys and as many notes; this is approximately the number employed in the whole of contemporary music. It is, of course, very small, but it will not seem so insignificant if we remember that the infinite variety of our world is due to the combinations of about the same number of chemical elements. The fact should be emphasized that we are speaking of European music only and are not concerning ourselves with the music of the Eastern races, whose scale comprises intervals of less than a semitone. The Arabs divide their octave into 17 and the Hindus into 36 parts, whereas we have only 12. The music of these peoples is purely melodic and is not harmonized. They are able to appreciate the relations of notes in sequence only, whereas the ear of the European can grasp the extremely intricate connexion between many parts sounding simultaneously within the limits of the 12-semitone scale. For our further elucidation an acquaintance with the mutual relation of the individual notes of the scale is indispensable.

If we make two notes sound simultaneously, our ear will distinguish their combination, which may change when we sound notes with a different number of vibrations. Here we get what is called in elementary theory an 'interval'. Our smallest interval will be a semitone, since our music is based on series of notes in which intervals of a whole tone and a semitone alternate. These series are the so-called scales. Each of us has probably had a plentiful experience of the effect of

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these scales on himself, has played them, or has suffered from the playing of them by others. Every scale consists of seven notes, such as C, D, E, F, G, A, B, which have the following upward relations: 1, 1, $\frac{1}{2}$, 1, 1, 1, $\frac{1}{2}$. In this scale all the intermediate semitones will be designated as a raising or a lowering of the notes forming an interval of a whole tone. For example, the intermediate semitone between C and D might be called a lowering of the note D, i.e. D flat, or a raising of the note C, i.e. C sharp. If we take the C and strike it simultaneously with each of the succeeding notes, we shall get a series of intervals, the number of which will obviously equal 12. These intervals are called seconds, thirds, fourths, fifths, sixths, sevenths, and octaves. They may be divided into agreeable (consonances) and disagreeable (dissonances), thus:

<i>Consonances</i>		<i>Dissonances</i>	
Octave	C—C	Augmented fourth	C—F sharp
Fifth	C—G	Augmented prime	C—C sharp
Fourth	C—F	Major seventh	C—B
Major third	C—E	Major second	C—D
Minor third	C—E flat	Minor seventh	C—B flat
Major sixth	C—A	5 intervals	
Minor sixth	C—A flat		
7 intervals			

But this division cannot be so categorically observed, and if I were to ask you to determine the allocation of an interval to either series you would find it a somewhat difficult task; the fourth, for instance, which theorists have regarded sometimes as a dissonance, sometimes as a consonance. Evidently, in addition to

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perfect consonances we must admit a transitional group of imperfect consonances. It is manifest that this division into consonances and dissonances would serve a clear purpose if we knew that the former might be employed in music and that the latter were quite inadmissible. The fact is, however, that at the present time dissonances are used as successfully as, and even more successfully than, consonances. But if we turn to the history of music we shall actually see that the division of intervals into consonances and dissonances was connected with the admission of the former into music and the exclusion of the latter. It is particularly interesting for us that the institution of these definite groups does not present itself as something immutable, which has accompanied music from its cradle down to the present day. Their content, as will be seen, has changed in the course of the centuries, the group of consonances having been slowly augmented by transferences from the group of dissonances. If we follow the gradual alteration of the idea of consonance and dissonance, we shall be able quite objectively to analyse the direction in which the advance of music progresses. The interval of a greater (major) third, with a distance of two whole tones, does not arouse in contemporary man any suspicions as to its harmoniousness. Yet there was a time when this indubitable consonance was regarded as a dissonance; and not until the Middle Ages was the major third added to the consonances. Thanks to this, it was long the custom to avoid the major third in final chords, and to end a composition with the perfect consonances

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of the octave and the fifth only. The minor or lesser third was included in the number of consonances still later. With composers of the Middle Ages, and even with Sebastian Bach (1685-1750), we constantly encounter major chords (i.e. chords with a major third) at the end of a minor composition. The acceptance of a dissonant combination in musical practice and its subsequent transformation into a consonance may therefore be investigated by means of historical data, which tell us that the introduction into the musical system and into composition of intervals now regarded as dissonant was an extremely gradual process. And yet to us they present themselves as combinations accessible to the most undeveloped ear and a source of enjoyment to it. Of the two fundamental chords of the ordinary concertina (the tonic and the chord of the dominant seventh), the latter was introduced only at the beginning of the seventeenth century, by Monteverde, who added to the major chord of the fifth degree the dissonance of the minor seventh.

If we had once for all an absolutely accurate definition of consonance and knew what distinguishes it from dissonance, then, of course, such transformations of dissonances into consonances would be abolished for the future. However, in spite of all the efforts of eminent teachers of physics and musical theorists we still lack such a definition.

Since every note can be expressed by a mathematical quantity—the number of its vibrations—they tried first of all to discover the characteristic ratios of the numbers of vibrations for consonances and dissonances.

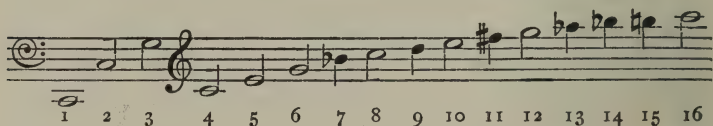
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Pythagoras, in the sixth century B.C., found that the ratios were extremely simple, namely the multiples 1 : 2, 2 : 3, 3 : 4, 4 : 5; but this of course does nothing to explain the essential nature of consonance and dissonance. Passing over the explanations of Leibnitz, Eilert, and others, we will briefly call attention to Helmholtz's theory. An acquaintance with this theory and with the theoretical knowledge essential to its comprehension will prove to be indispensable to its further elucidation. We must familiarize ourselves with overtones or upper harmonic tones and with the laws governing the vibrations of sounding bodies. It is well known that notes are of a complex nature, and comprise in addition to the clearly heard fundamental tone a further series of tones, distinguishable only by the ear which has been developed to a certain extent, and brought within our grasp by means of special resonating appliances. It is possible to demonstrate the overtones on a piano, without having recourse to such appliances.

For this purpose it is necessary to press a key—the C let us say—without sounding it and hold it down, the pedal being closed, at the same time striking the notes indicated in the music given on p. 14, and releasing them immediately they have been struck. If we strike the C of the next octave, we shall distinctly hear this note reproduced by the string C, although its own note gives an octave lower. We thus get the first overtone. By striking the note G we make the C string sound G, i.e. the third overtone, and so on. It is possible to get the simultaneous resonance of two,

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three, or more overtones if we strike the corresponding keys simultaneously. Another method of obtaining overtones is to strike a key and touch the vibrating strings with a slight pressure; then at the corresponding point the vibrations will cease, but will continue to exist in the remaining parts of the string. What are called nodes are formed. The high overtones are too faint to be clearly audible, and those of high notes are even beyond the limits of the human ear; hence the greatest number of overtones within our reach are those produced by the resonance of low notes only.



If we call the fundamental note unity and enumerate all the overtones in their order, the figure denoting an overtone will express the ratio of the number of its vibrations to the number of vibrations of the fundamental note. Thus, for example, the fourth overtone 'C' has four times as many vibrations as the fundamental. The study of overtones shows us that every note represents an extremely complicated phenomenon, wherefore simultaneous combinations of notes are so intricate that we are unable fully to understand them. As we shall see, the same string can give us various notes, according to the kind of vibrations we excite in it by means of resonance. We can make a string sound C₁ as C₂, D_o as Sol, and so on. This phenomenon is usually explained by the help of diagrams illus-

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trating the vibrations of the whole string, of the half, of the third, &c. If, however, we wanted to picture to ourselves the simultaneous vibrations in the presence of which a string will give us, let us say, overtones 1, 2, 3, and 4, it would prove to be an extraordinarily difficult task. How do we explain the appearance of the first overtone? We say that a node is formed at the middle of the string, at which point the particles of the string do not vibrate, and consequently the vibrations do not extend to the string as a whole, but only to its two halves. We find it difficult to depict the simplest case—that of a fundamental note and its first overtone. If the string vibrates as a whole, it cannot have a node at its centre, since the existence of a node depends on the disappearance of the vibrations of the whole string as such. The same remark applies to the remaining nodes. Therefore the explanation, sometimes encountered, of overtones as vibrations of individual sections of the whole string is not applicable when a string gives the simultaneous resonance of the fundamental note and all its overtones. According to Helmholtz, with the simultaneous resonance of, for instance, two overtones, nodes are not formed; the string vibrates throughout its length. Since for each overtone the string will have a definite periodic form of vibration, we shall get the aggregate of two forms, giving rise to a new form. It is extremely interesting that the celebrated French mathematician Fourier should have discovered the law of the composition of the sound vibrations especially concerned in the phenomenon of overtones before the overtones themselves

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were detected. According to Fourier's theorem, every arbitrary periodic form of vibration may be regarded as the sum of the simple vibrations, 1, 2, 3, 4, &c. times more than the number of vibrations of the given movement. Fourier thus gives intelligible expression to the phenomenon of overtones and their reception by our ear. These relations are, of course, precisely characteristic of overtones; and when our string sounds two or more overtones simultaneously, the vibration of the whole string will give a periodic form summarizing the simple vibrations of these overtones. Consequently the curve of the vibrations of each overtone in sum with the rest will represent a single line of vibration, of a regularly periodic form, which our ear will analyse into its fundamental parts.

What explanation, then, must we find for the phenomenon of overtones? A study of the structure of matter in general will supply us with a clue. If we admit that every section of a string retains its resonant properties no matter how often it is shortened, we shall come to the conclusion that its sound is produced by the vibrations of its minutest particles, of the atom itself, and not only of the atom as a whole, but also of each of its component parts. If we cut the string anywhere, each section when stretched on an instrument will give us all the overtones. That is to say, we do not get one overtone from one part of the string and another from the other part—we get the resonance of a complete series of overtones from each part. It is evident that this is possible only if all the overtones are obtained as the result of the motion of the indi-

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vidual molecule or particle. Every molecule in a state of resonance accomplishes a definite motion, but this cannot be the cause of the resonance of a whole series of overtones. We must regard it, according to Fourier's theorem, as the resultant of the motion of all the electrons. The simultaneous resonance of a series of overtones may be explained by the fact that round the nucleus of an atom it is not a single electron that revolves in an orbit, but a series of electrons whose velocities vary. And a series of motions of the parts of the atom must give us, as a final result, a series of sound vibrations of different velocities, a series of sound-waves varying in length. That is why we hear the simultaneous resonance of a series of overtones with the fundamental note. It is easy to imagine that the revolution of the electrons of the atom in every particle of a string will be transmitted to the molecules of the air, and by means of the air will again be transmitted to a string tuned to the fundamental note or to some overtone; or it will fall upon our ear and excite the sensation of sound, or will gradually die away and disappear. The manner in which our ear is constructed compels us to suppose that a number of different sound-waves may be aggregated into the periodic vibrations of a single curve, may pass through the needle of the gramophone and then be distinguished by the aural nerve as the sum of definite notes of varying pitch, intensity, and timbre. We know that the timbre of a note—its colour, by means of which we discriminate between the same note when produced by the voice, the trumpet, the violin, &c., depends on the resonance

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of a greater or lesser number of overtones. Why is it that the violin string, the vocal cords, the trumpet will infallibly produce a different number of overtones? This we can explain only by taking into consideration the chemical composition and atomic structure of the sounding mass. It is evident that the atoms of various substances will be differentiated from one another by the number of electrons revolving in various orbits.

It can easily be imagined that the substance having the most complex structure will give the greatest number of variations in the velocities of the electrons and excite the resonance of the greatest number of electrons. The albuminous particle—the particle of the organic matter of which the gut string is composed and of which our ligaments consist—this particle has, of course, the most complex structure, and the brass alloy of which the trumpet is made will be comparatively the least complex. That is why we can imagine that the living tissue of the vocal ligaments will produce a note with the greatest number of overtones, that the fiddle-string will give us fewer, and the trumpet fewer still; also that the trumpet note will be the least agreeable to our ear. This circumstance explains why old violins have a finer and more pleasing tone than new ones. As we know, the tone quality of new violins improves with constant playing, especially if the player is a fine musician. The fact is that in this case the motion of the electrons in the atoms of the string will excite certain definite motions only of the electrons in the atoms of the wood. Under these conditions the structure of the wood undergoes a peculiar alteration, so that in

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every atom of it as many motions of the electrons of varying velocity are stimulated as are necessary to produce the resonance of the greatest number of electrons.

We will now pass on to the scientific theories of consonance and dissonance. Helmholtz, on the basis of the overtones, conjectured that the degree of consonance

TABLE

Octave	1:2	1 2 3 4 5 6 7 8 9 10 2 4 6 8 10
Fifth	2:3	2 4 6 8 10 12 14 16 18 20 3 6 9 12 15 18
Fourth	3:4	3 6 9 12 15 18 21 24 27 30 4 8 12 16 20 24 28
Major third	4:5	4 8 12 16 20 24 28 32 36 40 20 25 30 35 40
Minor sixth	5:8	5 10 15 20 25 30 35 40 45 50 8 16 24 32 40 48
Second	8:9	8 16 24 32 40 48 56 64 72 80 9 18 27 36 45 54 63 72
Seventh	8:15	8 16 24 32 40 48 56 64 72 80 15 30 45 60 75

of two notes depends on the number of coincident overtones. If we take the notes C 1 and C 2, i.e. the interval of an octave, it is evident that the upper note repeats all the overtones of the lower and the only difference will be in the vibrations of the fundamental note of the lower octave. Everything else will coincide. In consequence of this we get a complete blending of the two notes. And as a matter of fact the interval of an octave gives the highest degree of consonance, the coincidence of all the overtones. A fifth will give

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the coincidence of three overtones only, a second of one, and in a seventh not a single overtone coincides with the fundamental note; therefore the seventh must yield the highest degree of dissonance. From the table on p. 19 we obtain a very harmonious presentation of consonances, which would seem to satisfy every logical requirement, but further explanations reveal much that is at variance with the actual facts.

The non-coincidence of the overtones is connected, according to Helmholtz, with the unequalness, the brokenness of a note, and this it is which produces an unpleasant impression on our ear. Let us imagine two notes with 100 and 110 vibrations per second respectively. For every 10 vibrations of the first note there will be 11 of the second note, i.e. the tenth and eleventh vibrations will coincide, but the others will not. The coincidence of similar phases of sound-waves intensifies a note, and the coincidence of dissimilar phases weakens it. Therefore during that second we shall get the intensification of the note ten times, and we shall hear ten beats, i.e. ten times a second the equalness, the regularity of the vibrations, will be broken. If we take notes the numbers of whose vibrations are such that the frequency of these vibrations is increased¹, we shall observe that the unpleasant sensation is intensified—the notes become dissonant. Notes giving 30–33 beats per second are particularly disagreeable. These beats cause a sensation as irritating as interrupted vision, flickering lights, the scratching of the skin. With an increasing number of beats this

¹ Up to a certain limit. (Translator's note.)

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unpleasant feeling diminishes, as the brokenness of the sensation gradually disappears.¹ It is indispensable, however, to take into account the magnitude of the interval, since with an identical number of vibrations the impression produced by chords will vary in conformity with the absolute magnitude of the number of the vibrations. The smaller this interval, the harsher the dissonance. If the interval is wide, a seventh for example, the unpleasant sensation depends on the beats formed by the overtones. So, according to Helmholtz, the disagreeable feeling caused by dissonant intervals is due to the beats formed either by the fundamental notes or by the overtones. There is much, however, to be said against this explanation.

It is found that consonant intervals can also produce beats, to the number of about 33 per second (the minor third E-G, for instance); finally, such consonances as the octave and the fifth, if we trill them, will set up beats and still remain consonances. In just the same way a single note by means of a special appliance can receive a shock and form beats, though in this case the conditions which lead to the formation of a dissonance are absent, as we are dealing with one note only. Furthermore, dissonances are possible without beats.

All these contradictions cannot be explained by Helmholtz's theory. Unfortunately, attempts made since those of Helmholtz to elucidate the essential nature of the consonance and the dissonance have not proved satisfactory. Such are the theories of Stumpf

¹ i.e. the succession becomes so rapid as to produce the effect of a continuous impression. (Translator's note.)

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and Oettingen. This shows that the blending of overtones is a very complicated phenomenon, which cannot be registered by the number of vibrations only; their form must also be taken into account—i.e. they must be considered qualitatively as well as quantitatively.

Experiments in this direction were made by Zambiasi (1903–1905), who makes the phenomena of consonance and dissonance depend on the physical peculiarities of sound. Like Stumpf, Zambiasi believes that consonances correspond to the complete blending of the notes and dissonances to the incomplete blending. And this depends not on a psychical process, but on a physical phenomenon—the formation of a new periodicity from the combined vibrations of both notes. For this purpose the following optical apparatus is used. Two tuning-forks or two vibrating tongues—strips of metal—are fastened at one end; to the free end a mirror is attached. Each tongue covers a hole in a closed box, through which a current of air is admitted. The tuning-forks or vibrating tongues must stand perpendicularly to each other, and the mirror must be so arranged that a ray of light directed on one is reflected on to the other and falls on a fixed screen or on a revolving mirror. Then with the vibration of the tongue we shall see on the screen the movement of the reflected spot of light, which describes a complicated figure; if the screen is revolved, we shall get a series of intricate curves. These are the so-called Lissajous's figures. Diagrams, Nos. 1, 2, 3, 4, and 5,¹ show the intervals of a prime, a fifth, a fourth, a seventh, and

¹ See Appendix I.

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a diminished fifth respectively. It is evident that, on the simultaneous resonance of the notes forming an interval, the dissonances will reveal extremely complex ratios of periodicity. If we analyse the periodicity of the recurring figures, our attention will be attracted to the increase in the length of the periods in proportion to the strengthening of our sensation of dissonance. The prime, giving a complete and absolute blending of the notes, has the shortest period; the diminished fifth (C sharp—G) has the longest. The periods of dissonances have the same magnitude as the low notes which are just within our hearing powers. For the reception of a musical note $1/20$ of a second is indispensable, i.e. if it is to be distinctly audible; if we are to follow continuously the vibrations received, a note must have a minimum of 20 vibrations per second. If the number is less than 20 per second, the vibrations will be aphonic—they will not give the impression of a note.

Zambiasi's numerous experiments prove that the reception of intervals is subject to the same laws as the reception of individual notes. In order that an interval may be distinctly heard, its periodicity must not be very long—there must be not less than 20 periods per second. Thus the major third, for example, is hardly audible as such if the lower note has 80 vibrations. The period of this interval, being four times less than the number of vibrations of the lower note, is equal to 20, and is just on the border line. Zambiasi's observations also refer to chords which likewise form periods of a definite length. The chord C—E—G, for instance, has

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the shortest periodicity and imparts a clear and precise sensation of consonance, which explains the vigorous, energetic character of the major third. The minor third is of a gentler, vacillating nature, owing to the greater length of its periods.

Leibnitz concluded that music was the unconscious delight of mathematics; but neither Leibnitz himself, nor the critics who followed him and scoffed at his assertion, suspected that it was a matter, not of reckoning the intervals within the limits of the first ten ciphers (which, of course, could only give pleasure to a child), but actually of very intricate mathematical relations, based on the movements occurring within the atom itself. For us it is most important to observe: firstly, that combinations of notes sounding simultaneously have the same periodicity as a single note; and secondly, that dissonances present a more complex tonal phenomenon than consonances.

In explaining consonance and dissonance we have hitherto taken only the physical side of resonance; but we shall not have a clear conception in this matter so long as we study merely the physical phenomena of sound, nor until we get behind the tympanum of our ear and master the secrets of the transformation of the vibrations of air particles into tonal reception, so as to discover the laws governing that transformation. Evidently we shall have to wait a long time yet—the human brain and its psychical activity are still a mysterious realm, the investigation of which will occupy more than one generation of inquiring minds. But whether we are guided by scientific principles or rely solely on

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our ear in deciding as to consonant and dissonant sounds, there is no doubt that the evolution of music is closely and particularly connected with that decision.

In view of all this, we must conclude that the dissonance, owing to its physical nature, presents more complex relations than the consonance, and that the introduction of the dissonance into the musical system and its adoption in music are possible only if the musical ear is developed to a certain extent. By this we do not mean the possibility of hearing a given note, but that of correctly appreciating the relation of that note in a system of other notes, of associating one note with others; or, to put it more simply, of 'understanding' combinations of notes more complex and unusual to the ear. If we do not understand the combinations presented to us by a composer, we speak of a 'string of notes' conveying no meaning to us.

The introduction into the musical system of this or the other dissonance shows that we have taken a step forward; but this movement is accomplished very slowly, and sometimes centuries pass before there is any advance. We see that in the primary stages of its development the human ear was satisfied with the simultaneous sounding of perfect consonances—primes, octaves, fifths. It is quite natural that a melody sung simultaneously by a male and a female voice should move in octaves. The movement of the voices in fifths was also satisfactory to the ear, but in the early stages of development thirds and sixths still seemed to be dissonant intervals. The inclusion of other intervals amongst the perfect consonances was a very gradual

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process. Franco of Cologne, in the middle of the twelfth century, makes distinctions between perfect consonances (the prime and the octave), middle consonances (the fifth and the fourth), imperfect consonances (the major and the minor third), imperfect dissonances (the major and minor sixths), and perfect dissonances (the minor second, the augmented fourth, and the major and minor seventh). It was only in the thirteenth and fourteenth centuries that the sixth gradually took place amongst the consonances. If we turn to our own musical developments, each of us will remember the time when Wagner's music seemed hardly comprehensible and full of dissonances; and we can trace the gradual change in our attitude towards it. Now we listen to it, accept it, and enjoy it just as our ancestors delighted in the Italian music which we now find so primitive that we can derive no real pleasure from it. Our ear is keener and demands more complex tonal sensations. But the new French composers appeared; and after them came Skryabin, Prokofiev, Myaskovsky, and others, and again we had to go forward and learn to understand still more intricate tonal relations. It is possible that for some of us this advance proves to be beyond our powers. For the establishment of new tonal associations, our psychical apparatus requires to be very flexible and alert; and it must be acknowledged that every individual cannot develop it indefinitely. Senile decay of the organism would, of course, appear to be the natural limit.

You have probably happened to hear some such expression as this, concerning Prokofiev, Stravinsky,

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Myaskovsky: 'I understand the music of Wagner and Skryabin, but this is beyond me.' A comprehension of Wagner and Skryabin certainly shows a satisfactory degree of development; but music becomes still more complex—and what are we to do? Before we can 'understand' the new music and find pleasure in it we must familiarize ourselves with new tonal relations; new associations must be established, the correctness and lawfulness of new dissonances and their mutual relation must be realized, and then we can pass on to the comprehension of the music and its new content.

And so, summing up all that has been said, we must consider the gradual evolution of music an established fact. The axis of this movement appears to be the progressive complication of the sound material, the introduction into music of more intricate tonal relations, which in our objective definition seem to be more dissonant. This gradually increasing complexity in the development of music of course gives us ample grounds for considering that the evolution of music is accomplished in the same way, generally speaking, as the evolution of nature, in the form of a steady movement towards continually increasing complexity. If it were possible to assume, and to prove, that the analogy between the evolution of music and natural biological evolution is of the same kind, it is doubtful whether this would satisfy us. The properties of consonances and dissonances hitherto investigated enable us merely to point out the existence of a parallelism between the evolution of music and the evolution of nature. But, as we have already said, the phenomena of sound show

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themselves to be very complex; and by extending our analysis we can obtain a deeper insight into the evolution of music.

If we analyse the sensations produced by consonances and dissonances, we shall certainly observe first of all that consonances give us a sense of satisfaction; we feel that they are self-sufficient, self-contained, and make no further demand on our consciousness. But it is another matter when we hear a dissonance. It provokes in us a feeling of dissatisfaction, and unconsciously we long for a consonance; but it must not be a haphazard one—it must be definitely related to the dissonance to which we have listened. For a particular dissonance there may be more than one consonant combination which will satisfy our ear. Let us take for example the diminished fifth or augmented fourth, a dissonance for which there are six possible resolutions. This interval is remarkable for certain peculiarities, and not without reason was known in the Middle Ages as ‘*Diabolus in Musica*’. As a matter of fact, it displays a certain instability and imparts a sense of strain, of tonal gravitation, which disappears when we hear it resolved into a consonance. If we knew the exact scientific explanation of this instability, this gravitation, we should not be obliged to have recourse to our own impressions. Nevertheless we find in nature very many analogous phenomena. It will suffice to point to the attraction of positive and negative electrical charges, to the irresistible tendency of an acid and an alkali to combine in the form of a salt. It is evident that in the given instances there is a certain unstable

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condition, which may become stable by fusion with another unstable system, the combination of the two resulting in a more stable system. How are we to understand the instability of the dissonance B-F? Is there really a gravitation of the notes themselves to unite with a definite consonance? Or is it merely a requirement of our tonal reception? And is this gravitation, this instability only the result of our imagination? The fact of the gravitation of one note towards another is not indicated by acoustics. They may form a more complex or a more simple relation, but the phenomena of sound in their physical nature do not go beyond that. The very fact of the conversion of a consonance into a dissonance in the course of a certain period of time shows that the change which takes place is not connected with the number of vibrations, but with a psycho-physiological process in our brain. To explain what happens in our brain when we hear a dissonance, or its resolution into a consonance, we may to a certain extent employ the theory of conditional reflexes. By the term reflex we understand the reaction of an organism to an external stimulus or irritation, proceeding from the external world. Light falling on the eyes always causes a contraction of the pupils; irritation of the mucous membrane of the mouth by food substances is followed by secretion of the saliva. These are conditional reflexes. With a conditional reflex the unconditional connexion of phenomena is absent—under certain circumstances an external stimulus may cause a reflex, under others it may not. If we sound the note C and a minute later

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give meat to the dog, there will be a conditional reflex; as soon as the dog hears that note its saliva will be secreted—the conditional reflex has taken place. If we sound another note which is not followed by feeding, there will be no saliva. By means of an operation we can lead the duct of a salivary gland outwards, so that it reaches the skin; the saliva will then be secreted externally through the orifice of the duct, and will flow in drops. This operation is performed in I. P. Pavlov's laboratory, where the psycho-physiological section is treated in accordance with the method of conditional reflexes. The reflex that has been established can be destroyed by withholding the meat after the note C has been sounded: the note then becomes of no consequence to the dog and the saliva will not be secreted.

As regards the question in which we are interested—the absolute necessity that a dissonance should be resolved—we may say that in our case a conditional reflex to the given dissonance is set up. A connexion is established between the dissonance and the resolving consonance which follows it. This connexion is conditional—it may be destroyed and replaced by another. Thus for the dissonant interval B-F a conditional reflex is established: when we hear B-F we know that it will be immediately followed by C-E. Thereby the arch of the reflex is closed, and after the preceding tension, after a period of unstable equilibrium, stability is attained. As a conditional reflex is the physico-chemical process of ionic reaction, we may imagine that in the nerve-cells, under the influence of irrita-

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tions transmitted by the auditory nerve, the process indicated takes place, as a stage of unstable equilibrium, which comes to rest after a second irritation of the auditory nerve, this time by a consonance. A reflex to the sequence of the third of the chord of the dominant seventh and its resolution into the fundamental tone of the first degree is set up. But this reflex is conditional—it does not exist for an Arab, a Chinese, or an Eskimo; it has a significance only for a cultured European whose musical knowledge has been definitely developed. This reflex, however, may be destroyed if a composer can find other conditions for the establishment of an equilibrium. Grieg, in fact, has discovered another resolution for the third of the chord of the dominant seventh; he resolves it, not into the fundamental tune of the chord of the first degree, but into the fifth. Thus we have a new condition of stable equilibrium for the given intervals.

The introduction of the idea of the instability of intervals is due to the eminent Moscow theorist B. Yavorsky; and so far as I can appreciate its general outlines it appears to be extremely important to the understanding of music as a whole, and of its evolution in particular. We shall make further use of this theory in all its aspects for a detailed explanation of our subject.

An unstable interval may be likened to an unfinished arch, the middle portion, which closes the arch, being deficient. The unstable equilibrium of the initial sections of the arch stimulates in us a desire to pass on to a condition of stability, and the completed arch

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satisfies that desire. The leaning tower of Pisa presents a striking instance of an architectural dissonance which, we feel, needs to be resolved into a consonance, i.e. to be restored to a condition of stable equilibrium, since our intellect refuses to recognize the stability of the tower in its present position. It may be that the architecture of the future will include leaning, dissonant structures in its economy, and to coming generations they will seem as natural as the dissonances of Wagner's music—at one time the music of the future—are to us.

In employing the theory of instability we would point out in a general way that the interest of music consists, so far as we are concerned, in the state of tension resulting from the use of dissonant intervals, and in the transition from that state into one of rest or tonal equilibrium, brought about by the resolution, by the transformation of the dissonances into the corresponding consonances. A sense of tranquillity, and afterwards of indifference to the sounds, is effected by consonances only; on the other hand, a series of nothing but unresolved dissonances causes a feeling of annoyance, which may become extreme (Schönberg's music is a conspicuous example of this).

The gradual growth of dissonant combinations compels us to describe the evolution of music as a movement from stable and comparatively simple tonal relations towards instability and greater complexity. Granting this definition, we find that the bases of the evolution of music and of matter are identical—in both cases there is an irresistible advance from simple,

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stable equilibrium to complex, unstable conditions, from simple forms to complicated forms.

It must be recognized, of course, that the relations of the chemical elements from which lifeless, inorganic nature builds up inorganic substances are simpler and more stable than those of the elements used by living nature in creating organic matter.

It is only by degrees that nature has advanced from the creation of inorganic combinations of elements to the creation of living, organic, and organized combinations. The most complex are the albuminous substances (such as the nucleo-proteids), the components of living matter, of the complex forms of the living world. The most characteristic feature of a complex albuminous substance is the extreme instability of the albumen molecule; this enables it constantly to combine with other elements, but at the same time the union is never permanently stable. Drawing an analogy between the structure of a compound substance and musical structures, we may say that a state of instability is peculiar to both. Complex musical structures built up of dissonant intervals, which cause extreme tension and act most powerfully on the hearer—these structures, a triumph of our time, are the supreme achievement of the creative spirit, and demand of composers possessing a great gift for combination the solution of intricate constructional problems. They demand this, because a musical composition attains the ideal, not when it comprises the greatest number of dissonances, but when the mutual relations of the accumulated tone material are logically achieved. It should

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represent the highest organization of that material, just as an albuminous substance represents the highest degree of organized matter. The discovery of new laws of unstable equilibrium is the end that will be attained by the innovator who reveals new paths of art.

In this respect architecture and engineering offer a solution of similar problems. How simple is the colonnade of the Greek temples, where the horizontal members resting on the columns give us the simplest and most stable forms of equilibrium! Take the Etruscan arch, with the locking cuneiform stones. Look at the Gothic ogival arch, in which the lateral thrust is counteracted by means of flanking buttresses. Lastly, consider the structures of the present day, the American sky-scrapers, the bridges flung across great spaces and held in the air by a seeming miracle. All these are solutions of the most complex problems of equilibrium. And if contemporary structures appear marvellous, contemporary music, in solving such extremely difficult problems of tonal equilibrium, seems to be just as miraculous.

The creative spirit of man had to travel far along the road to perfection before it attained the heights to which it has now risen. The fruits of the creative power of contemporary art are seen in its complex musical forms, whose relation to the primitive forms of the dawn of musical development is as that of the free-fluttering butterfly, embellished with intricate patterns in brilliant colours, to the shell of the mollusc.

Thus, by merely considering the question of the

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stable or unstable equilibrium of consonant and dissonant intervals, we are able to picture to ourselves the evolution of music. We may apply a similar argument to painting and sculpture.

✓ In painting, an accurate depiction of the subject with all its most insignificant details gives an impression of stability. When the outlines are obscure, when there is a certain vagueness of colouring, and the details are indistinct, there is a sense of unstable equilibrium. Make a sketch of a cyclist in motion, showing every detail of his costume, his bicycle, and every spoke in the wheels—that will be stable equilibrium. Observe how a cyclist is represented in the advertisements of to-day—instead of the separate spokes you see a series of concentric circles, and you get an impression of instability, of motion. The old master painted on his canvas a moment of immobility—of stable equilibrium. The flying angel hangs motionless in the air; there is no movement in the trees, for every leaflet is shown. In the little picture attributed to Leonardo da Vinci, the *Mona Lisa*, the most slender hairs are depicted. Enlarged to life-size, the leaves of the tree would be as big as, if not bigger than, a man's head, and the hairs as thick as ropes. Nevertheless this did not trouble the old masters—they had to portray every detail in order to establish stability. But the evolution of painting is in the direction of an ever-increasing instability. The contemporary artist does not give us accurate, sharply defined contours, he does not give us details—he aims at a condition of unstable equilibrium. For this purpose he even violates the laws of

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perspective. He paints a tree with broad sweeps, and of course not a single leaflet can be discerned. Hair is treated with similar boldness.

Compare any portrait by an old master with Serov's 'Rimsky-Korsakov', and you will at once decide that the former gives an impression of stable equilibrium and the latter of unstable equilibrium and vitality.

It is the same in the case of sculpture. The old master assiduously polished the whole of the surface, worked up the details, supported the body of the lion or the horse by a stay in the centre—everything was in a condition of solid stability. Compare the sculpture of to-day, in which rugged surfaces, a certain vagueness of outline, and a lack of finish give an impression of instability. This tendency of the evolution of art is particularly evident in photography. The photographer used to photograph his subject accurately and get every detail, but nowadays he purposely alters the adjustment of the apparatus and the time of exposure, in order that the photograph may not be exact—may be unstable and more vivid.

All this should be sufficient to reveal the essential nature of the evolution of music and its biological bases. It is subject to the same biological laws as the whole of organic, living nature. This very symptom of stable and unstable equilibrium leads to the admission of the continuity of musical evolution. Evolution must be connected with the unceasing generation of new forms and the extinction of the old. Such is the biological law for every living organism, and it has absolute sway in the world of musical organisms or

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forms, from the simplest folk-songs to the most complex symphonies of our day. And here again music is at one with nature. It is impossible to imagine that as soon as a new, more complex organism—one most nearly approaching the ideal—is created, all the less perfect forms by which it was preceded immediately disappear. No; the simplest organisms continue to exist side by side with their successors, but gradually die out and vanish from the face of the earth. At the same time they may leave traces behind them, hidden away in the archives of the libraries. It is even possible that some day they may be heard again amidst generations to whom they are unknown; but these attempts to revive dying organisms cannot restore them to actual life. They are in fact eliminated from musical life—they are dead. A vast number of masses, oratorios, and choruses are already consigned to oblivion. It must, however, be explained that it is only musical compositions and forms that die: music does not.

You may often have heard it said—perhaps you personally have said—that music came to an end with Beethoven, Chopin, or Wagner. For one it is Beethoven, for another Chopin, for a third Wagner. Such an assertion will be true only for him who takes up this position, and will refer entirely to his individual musical development—for which, of course, a certain definite limit exists. It may be that to one of us Chopin's music affords the highest enjoyment, thus entirely satisfying every requirement of his soul. Hence it is quite natural for him to declare that, so far as he is concerned, music died with Chopin. This merely

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proves that the circle of his musical evolution is complete and that his musical development has ceased. But this does not mean that music also is dead; it goes on its way just as hitherto. Every one, however, cannot develop his tonal capacity indefinitely; and that is why music progresses so gradually.

Gifted natures alone rise in their development far above the level of their contemporaries. The geniuses are the pioneers, opening out new paths along which all movement is directed. This is the reason why for us—the common herd—there will always be a music of the future. It is this music which our descendants will know, and for them our music will be the music of the past. To those who were brought up on Italian music, Wagner's was music of the future—the music of the Wagner who, according to the admirers of the Italian school, wrote only one tune—'Star of Eve' in *Tannhäuser*—the music which reminded César Cui, the composer, of 'the screeching of beasts'. Probably the transformation of Wagner's music from the 'music of the future' to the music of the present was accomplished under the eyes of many of the readers. And now again we stand perplexed before the 'music of the future' which has arisen since Wagner, the music of Schönberg and other composers, of whom it cannot even be said that they have written one tune. And once more we exclaim indignantly: 'Bless my soul, it's nothing but a string of dissonances.' Yes, it's quite true. And all it means is that the development of music in general goes on indefinitely. It would, of course, be very interesting to discuss the

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question of the drift of its evolution, to investigate the branching paths by which it travels, and which often lead to a blind alley where involution is already beginning. For although the movement of evolution is accomplished in one direction, it follows different paths.

Evolution cannot proceed indefinitely in every direction—it is checked by the aggression of involution. The latter attacks when evolution exceeds the limits necessary to the organism. If we turn to one aspect only—the size of an organism—we shall see that evolution in striving for excessive magnitude brings about the destruction of the organism. The gigantic reptiles of the cretaceous period perished by reason of their enormous bulk. They proved to be unfitted for the struggle, too sluggish and clumsy. Zeppelin's immense airships, the huge submarines, and, we may add, Wagner's colossal operas, which require an enormous orchestra—all these transgressed the limits upon the observance of which the vitality of these products of technical science and art depended. The vast, unwieldy Zeppelins became the victims of a few aeroplanes: the submarines were sunk because their eye—the periscope—offered an easy target and its destruction involved the destruction of the vessel. Despite the irrestrainable aspiration of the Germans for the gigantic, in Germany itself protests are heard against the enormous Wagnerian orchestra, which imposes an excessive strain on the singers, and against the cumbrousness of the Wagnerian operas. And the successor of Richard I, Richard (Strauss) II, in view of this opinion sometimes

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reduces his orchestra almost to the dimensions of Mozart's. In just the same way, colossal symphonies such as Mahler's exceed the limits necessary for the highest development of the musical ideas implanted in them. Earlier, the path which led to the creation of the great examples of religious music, and to the supreme development of the contrapuntal style—this path completed its appointed cycle and the evolution of music followed another road. For musical organisms must also be adapted to their environment, and must undergo changes parallel to those established by biological laws. In these days nobody would take it into his head to compose masses and oratorios in the contrapuntal style, since the suitable conditions do not exist; our altered environment makes it impossible, and our religious sentiment finds other means of expression.

So far as the music of the future is concerned, we are certainly not in a position to decide immediately if the new path into which musical evolution may be diverted is the right one, nor to predict whither it will take us. We must have confidence in the leaders, the creators of genius, who alter the course of evolution with an authoritative hand, guided by the natural instinct implanted in them, which finds its justification only in the historical perspective of the road which lies behind them. At the same time the inertness of the musical mass provokes the bitter struggle which has its perfect analogy in the biological struggle for existence.

Meanwhile, let us pause to sum up what has been said. So far we have employed the symbols of stability

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and instability mainly in order to give the reader a clear idea of the bases of musical evolution; to show that it takes place in accordance with a definite plan; to indicate the direction in which it is accomplished; and to prove that the laws governing the movement of musical evolution are the very biological laws which control the evolution of the whole world. So that the evolution of music may become still more comprehensible, we shall have to proceed to the examination of the material from which are constructed musical productions—those castles in the air, passing before our senses in the form of sounds and being transformed into whimsical shapes. We shall try to show that the evolution of music depends on the evolution of the tonal material introduced into it.

Every musical work, as we know, may be reduced to a little series of notes, arranged in a certain systematic order. We have only to glance at the keyboard in order to grasp mentally the whole of the tonal material out of which all our music is constructed, and to notice the separate sections into which the keyboard may be subdivided. Since for us the smallest interval between two adjoining notes is equal to a semitone, each series comprises 12 semitones. In this way the whole keyboard is divided into 7–8 octaves. Starting from the series of 12 equal intervals of a semitone, we can alter its form, i.e. we can construct a series with different relations, with intervals not of a semitone but of a whole tone, of 3 semitones, of 2 whole tones. Series of such kinds are modes or scales; and they constitute the basis on which musical productions are built up.

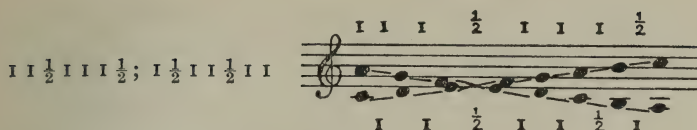
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The alteration of this basis is closely connected with the evolution of music. Every period was founded on its scales, and the evolution of music went hand in hand with the changes in their form.

What is the minimum quantity of tone material necessary to start the primitive musical organism in the form of a self-contained unit? Two notes, B and C for example, will suffice. Given these two notes, it is quite possible to create a certain intonation, to arrange them in a certain metrical correlation. Of course it is primitive music, which could only satisfy the ear of a savage in the lowest stage of development.

The introduction of a greater number of notes makes it possible to produce more complex constructions. This is the path by which musical evolution has had to travel. It must be recognized that the most ancient melodies were formed of an insignificant number of notes. Sequences of five make up the scale on which the Chinese and Scottish tunes were founded. Amongst the Greeks there existed series of four notes—the so-called tetrachords—from the combinations of which modes and scales were formed. Pythagoras established the eight-note scale. As the tetrachord admitted of any relation of tones and semitones by the change of the position of the semitone, it was possible to construct several varieties of tetrachords, and by blending them to form several types of scales. These were the so-called modes, upon which the music of the Middle Ages was founded. In the course of time two modes, corresponding to our major and minor scale, proved to be sufficient:

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A long period elapsed before the predominance of the major and minor scale in European music was established; but the development of music of course continues, and is connected with further changes in the form of the tonal basis—changes in the direction of greater complexity, for which there is an enormous field. We can not only alter the relations of the intervals within the limit of our 12-semitone octave—we can introduce entirely new relations by changing the pitch, i.e. by using intervals which only approximate to semitones and do not coincide with them. Thus if the relation of the notes in a major scale is expressed by the figures 2 : 3 : 4 : 5 : 6, we have merely to continue the series and construct intervals having the relation of 4 : 7, &c. The development of our ear is, of course, in advance of our theoretical principles; and by virtue of this we find in the music of our time the employment of very complicated scales, which give us very intricate tonal combinations, exceeding the limits of the hitherto unaltered scale. The fact is that the fixed scale is peculiar to our pianoforte and organ. The wind and stringed instruments, like the human voice, can vary the size of their intervals, and are not restricted to the decreed minimum of a semitone. In consequence, side by side with the tempered scale of the pianoforte with an equal number of vibrations

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for sharps and flats, the voice and the orchestral instruments can adopt the natural scale, in which raising and lowering will differ as $9/8 : 10/9$ ($81/80$). Besides this we have the inherent faculty of consciously fixing the definite relations of notes, though in actual fact the mathematical ratios do not quite coincide with our idea of them. This faculty of accommodation goes the length of enabling us distinctly to accept one and the same interval as either a major or a minor third.

If we divide our scale into seven equal parts, we get the Siamese scale; if into 1,000 equal parts, these equal intervals of the Siamese scale differ from one another by 142-thousandths. Wooden harmonicons tuned to the Siamese scale when struck will give the impression now of a major, now of a minor chord, though in actual fact the ratio of the intervals of the chord remains mathematically the same. In contemporary music, of course, accommodation is used to a much smaller extent. In any case we must assume that when we listen to contemporary music our estimation of the intervals is not quite the same as when we hear the compositions of Beethoven or Bach. That is why it is perfectly natural to suppose that the further evolution of music will be connected with the introduction of new scales and an alteration in size of the minimum interval. Although this is at present considered to be a semitone only, we know that the musical ear can easily appreciate a far smaller fraction of a tone.

Undoubtedly it will be a considerable time before we can introduce the new system of scales with new and more minute intervals, and create a system of

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mutual relations between the much greater number of notes which the octave will comprise.

It is possible that some one may ask: 'Do you mean to say that the whole essence of the development of music consists in the finding of fresh combinations of notes? Hasn't the major and minor scale been quite sufficient for the creation of new and genuinely inspired compositions since the days of Beethoven, Chopin, and Wagner? Isn't it enough that a composer should conceive a fine idea and be able to express it by the old means? Surely the essential nature of music doesn't lie in this or the other number of new chords, new dissonances, but only in the depth of the mood, in the profundity of the thought, in the width of the creative spirit's range?' To this we must reply: 'It is not so.' If the poet finds new words with which to express his thoughts, and the artist new colours and new ways of blending them, then the great composer must introduce new elements into his work: he cannot restrict himself to the tone material which his predecessors have exploited. With the major and minor scale it may seem possible to form endless combinations of every conceivable kind; but this possibility is not unlimited, since we require more than a mere collection of notes—since they must be blended into one complete and harmonious tonal structure, bound together by the laws of musical equilibrium. The number of combinations of such a nature, no matter in what scale, gradually becomes exhausted. They begin to repeat themselves, they no longer impress us as they did before, they have lost their novelty. The

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coinage shows signs of wear. The composer who limits himself to material which has already been used, runs the risk of perpetually coming into contact with hackneyed combinations associated in our minds with the musical ideas of other composers. Whether he likes it or not, his compositions will resemble too closely those of others and his individuality will not show itself. This happens time and again with composers whose creative powers are feeble—sufficient only for the making of variations on combinations already discovered, and for the creation of ‘music of the present’. Of course evolution is not achieved by the possessors of such talents, who merely play the part of a transmitting apparatus, propagating and making more accessible to the masses the new thing brought into music by genuine creative genius.

The advance of music is accomplished with a great deal of friction, connected with an unceasing struggle. Every period, as we have said, is fettered by a certain scale; and the effort to escape is attended by the bitter resistance of erudite theorists, composers, performers, and the public, who refuse to understand new compositions filled to overflowing with dissonances of all sorts. Their composer has to endure the vigorous onslaught of this chorus; to plead for the performance of his works; to propagate his new music; to find publishers; to continue to create, overcoming all the difficulties piled up on his life's path.

Thus the biological law of the struggle for existence becomes effective in music. Here, indeed, that struggle is carried on mercilessly, not only for the recognition

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of new musical ideas, but also for existence in the real meaning of the term. Take the biography of any eminent composer, and you will be amazed at the mass of deprivations which had to be endured by the man who sacrificed his whole life to his beloved art. The most striking instance of this is, I think, the vital struggle forced upon Beethoven and Wagner. This question is so interesting that it would provide the theme of a separate article, but we cannot consider it here.

It is inadmissible to discuss the biological bases of the evolution of music without dwelling on the law of heredity—the law which regulates the movement of evolution, making it a gradual and sequential process. In order to profit by this law of the theory of evolution, we must picture to ourselves an incessantly developing series of musical forms in their historical sequence, and notice how the distinguishing features of a form are passed on from one musical production to another, in the course of which evolution they undergo changes for the better or for the worse. We shall then establish their heredity, thanks to which the subsequent forms, in acquiring those features from their predecessors, develop them and in their turn pass them on to their successors. The expression ‘musical forms’ is here used in a somewhat general sense, not in the restricted meaning of the term, as understood in the theory of composition. As employed here it is synonymous with ‘individual’ or ‘organism’.

It is quite evident that a separate article might also be devoted to the investigation of the heredity of

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musical forms. We will, however, content ourselves with indicating briefly that, applying the law of heredity to them, we can establish their gradual, sequential development, the characteristic signs of a form being handed down from one production to another, in the spirit of Darwin's doctrine of heredity. As an example we may cite the development of the symphony in the works of Haydn, Mozart, and Beethoven—in the order of sequence. But in addition to the orderly system of changes, we can point to cases in which new features, whose origin cannot be attributed to heredity, suddenly reveal themselves in a given musical form. Such features come under the theory of variation, which was worked out by Korzhinsky and Defries, and by which we account for the growth amongst the normal flowers of the petunia of a double-petalled bloom—the progenitor of a whole race—and for the appearance of the red-leaved barberry at Versailles in the early years of last century.

An instance of this phenomenon of variation is, I think, Beethoven's Sonata in C sharp minor (commonly known as the 'Moonlight') in which the first movement of the ordinary sonata form is unexpectedly replaced by an Adagio. Another example is the finale of Tchaikovsky's Sixth Symphony—Adagio lamentoso instead of the usual Allegro. Of course we do not encounter such instances at every step, nor do they occur frequently in nature.

Adaptation to environment plays as important a part in the evolution of musical forms as in nature, increasing the development of some forms and definite

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characteristics and causing others to disappear. Adaptation is therefore a powerful factor in this development. For example, in the second half of the seventeenth century, vocal virtuosity was the predominating feature of opera in Italy. This was due to the appearance on the operatic stage of castrati, who had to amaze the public by displays of exceptional skill and brilliancy. Adaptation to environment also accounts for the increased development of the forms of sacred music, which continued until the seventeenth century. It is doubtful if any contemporary composer would in these days follow the example of Johann Sebastian Bach, who wrote sufficient church cantatas for five years' complete services. Adaptation to environment calls other forms into existence. Religious music is not widely diffused nowadays and seems to have been replaced by dance music.

Thus in the evolution of musical forms changes in their characters are brought about and strengthened by adaptation to environment, which consequently affects the subsequent series of musical productions. At the same time, in addition to inherited qualities we sometimes observe the sudden appearance of new features in the shape of variations.

Throughout the universe the characteristic traits of periodicity and symmetry may be observed; at one end of the scale we see them in the motions of the electrons within the atom, at the other in the movements of the planets. Periodicity is extraordinarily characteristic of music. Take the note itself—its vibrations are broken up into a series of periodic sound-waves. Our

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tonal system, again, is strictly periodic. It is split up into periods, each consisting of twelve semitones. And since periodicity is common to the whole of nature, we ought, of course, to find somewhere an analogy to our tone system. As a matter of fact, we know that in chemistry there exists a periodic system of the elements, established by D. I. Mendeléev; and in view of the molecular basis of sound it will, I think, be interesting to draw a parallel between his system of the elements and the European tonal system.

As we know, all the chemical elements forming the basis of every substance found in nature may be arranged in nine vertical columns and twelve horizontal rows, in the order of their atomic weights. Those in the vertical columns have similar, recurring properties. The gaps in the table are left for the elements which have not yet been discovered. Since Mendeléev founded his system a considerable number have been brought to light and have taken their places in the table. It contains 108 spaces and in them all the elements should appear. Hence this table with its similar elements forming periods cannot but suggest an analogy with the musical octaves. I have arranged all the notes of the nine octaves used in our music in nine vertical columns and twelve horizontal rows, in accordance with the increase in the number of the vibrations, to correspond to Mendeléev's zero column. I have called the 32-foot octave zero, as its notes are rarely used. The twelve horizontal rows contain in their order the notes of the twelve semitones; therefore each vertical column gives us an octave of twelve

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semitones, and each horizontal row notes having the same name but separated by an octave. The figures beneath indicate the ratio of the number of vibrations of the given octave to the number of vibrations of the sub-double octave, which is taken as the unit. We get the series of numbers: 1, 2, 2×2 , 2×4 , 2×8 , 2×16 , 2×32 , 2×64 , 2×128 , representing a geometrical progression.¹

This means that the whole of the tone material of our music enters into a periodic system, thereby emphasizing its naturalness based on the profound properties of the structure of matter. We say that our music has no type in nature; and yet our tonal system is typified in that of the chemical elements—a system also founded on the most subtle peculiarities of molecular structure (the atomic weight is equal to the number of the electrons). The identity of the figures is amazing: there are the nine vertical columns and the twelve horizontal rows; the numbers of the elements and the notes are equal; and the periods they form—the chemical and the musical octaves—consist of eight elements and twelve semitones respectively. The notes of the system are those of the tempered scale. If our system had included intervals constructed in relation to the number 7, we should have had a natural and a tempered seventh and other intervals. But even in this case the resemblance to the periodic system of the elements would have remained, since the atomic weight of an element may vary in accordance with its origin; for example, there are three forms of lead.

¹ See Appendices II and III.

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It would, of course, be unreasonable to look for exact coincidence, as acoustic phenomena are only physical, not chemical. As will be seen, the similar elements appear in the vertical columns in Mendeléev's system, but in the horizontal rows in the periodic system of notes. The valency of the chemical elements, which is determined by the number of oxygen atoms combining with them, represents an arithmetical progression, and the indices of the number of vibrations of the octaves a geometrical progression.

Another prototype of our tonal system is the system of overtones—it comprises the basis of our scale and our harmony. That is why our system of notes, founded on the prototypes furnished by nature herself, is capable of evolution, to which not one of the Oriental systems lends itself. The ulterior course of evolution is indicated in the system of overtones. Determining the scale hitherto on the basis of the first overtones, we gradually introduce the next, and if we have already accepted a scale constructed on the overtones 1, 2, 3, 4, 5, 6, then the subsequent scales will be built on the intervals from 7 onwards. Thus the European ear has comprehended the bases of tone, has instinctively guessed its structure, and has created its own tonal system in accordance with the example set by nature herself.

Underlying our musical form we have also the law of periodicity and symmetry, and again we find the prototype in the periodicity and symmetry of animal and plant forms. We may imagine that the whole universe, filled with worlds revolving in their orbits,

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gives the note with all its overtones and forms the harmony of the spheres, which reverberates in our soul and is incarnated in our music.

Einstein's principle of relativity has now obtained general recognition. Most people are, of course, acquainted with the fundamental proposition of his doctrines. According to Einstein there is no such thing as absolute time, absolute space, absolute scientific truth, absolute form—I cite only a few of his theses which may be of interest in connexion with music. Science must for ever renounce the possibility of knowing absolute truth—our knowledge is restricted to relative truth only, and we must recognize such as absolute. If the attainment of absolute truth is beyond the reach of science, the attainment of absolute beauty, absolute perfection, absolute form, is equally impossible for art. If there is no absolute truth, there is no absolute beauty, but there is a relative beauty, there is a continual attaining of a perfection which always falls short of the ideal of absolute beauty. For the realization of that ideal would signify the death of art, the end of its evolution—the dynamic would become the static, a condition of absolute equilibrium would result, rendering any further advance impossible.

Many will, of course, disagree with this thesis. There are those for whom the absolute ideals of musical beauty have already found expression in such works as Bach's B minor Mass or Beethoven's Ninth Symphony. But they are the incarnation of relative beauty only, and not of absolute beauty. Let us not close our eyes to historical facts. We know that at one time Pales-

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trina's music was recognized as the ideal of absolute beauty, but now that ideal has for us merely a relative value. It is doubtful if in these days any one would be drawn to this music as the ideal which satisfied his spiritual needs. And if the Ninth Symphony is for many absolute, unexcelled beauty, for many more it is not so. It may be anticipated that in the course of time Tchaikovsky's Sixth Symphony and Skryabin's Third Symphony will be added to the list of such unsurpassed examples of absolute beauty. But has the impossibility of attaining the ideal of absolute beauty any significance for the evolution of music? Certainly—a very great significance. However splendid our first achievements, we must inevitably continue our advance along the path which leads to the unattained ideal of absolute beauty. Such is the immutable biological law—ever urging us on, ever summoning us to the more complex. The ascription of absolute perfection, absolute beauty, to any particular work fetters any further movement. If the Ninth Symphony is the ideal, what is left for subsequent creators? Merely imitation, since absolute perfection is incapable of improvement. Once the pinnacle of art is attained our journey is ended. But in actual fact it is otherwise: life inexorably draws us on and compels us to struggle with might and main for the further evolution of music. Life bids us put aside the shade of a gifted creation if it obscures the light needed for the development of subsequent creations. By recognizing that only the relatively beautiful exists we are enabled to sanction the further development, the further evolution of music.

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Since the time of the Ninth Symphony music has made great strides—in the direction of greater complexity. Contemporary composers are solving problems far more intricate than those of Beethoven's compositions.

Let us refrain from the perpetual contemplation of the most splendid achievements of the past; let us turn our gaze to the unattainable ideal of beauty that lies before us. Let us say to our young and growing talents: 'See, these are the heights to which contemporary art has risen. It is for you to go forward; on you is laid the burden of problems still more difficult than those already solved.'

Such is the biological law—ever onward, ever towards a more perfect ideal!

APPENDIX II

Mendeléeff's Periodic System.

	O	I	II	III	IV	V	VI	VII	VIII
1	—	Hydrogen H 1·008	—	—	—	—	—	—	—
2	Helium He 3·39	Lithium Li 6·94	Beryllium Be 9·1	Boron B 10·9	Carbon C 12·0	Nitrogen N 14·01	Oxygen O 16·00	Fluorine F 19·0	—
3	Neon Ne 20·2	Sodium Na 23·00	Magnesium Mg 24·32	Aluminium Al 27·1	Silicon Si 28·3	Phosphorus P 31·04	Sulphur S 32·06	Chlorine Cl 35·46	—
4	Argon Ar 39·88	Potassium K 39·10	Calcium Ca 40·07	Scandium Sc 44·1	Titanium Ti 48·1	Vanadium V 51·0	Chromium Cr 52·0	Manganese Mn 54·93	Iron, Cobalt, Nickel Fe Co Ni 55·85, 58·97, 58·68
5	—	Copper Cu 63·57	Zinc Zn 65·37	Gallium Ga 69·9	Germanium Ge 72·5	Arsenic As 74·96	Selenium Se 79·2	Bromine Br 79·92	—
6	Krypton Kr 82·92	Rubidium Rb 85·45	Strontium Sr 87·83	Yttrium Yt 88·7	Zirconium Zr 90·6	Niobium Nb 93·5	Molybdenum Mo 96·0	—	Ruthenium, Rhodium, Palladium Ru Rh Pd 101·7, 102·9, 106·7

7	—	Silver Ag 107.88	Cadmium Cd 112.4	Indium In 114.8	Tin Sn 118.7	Antimony Sb 120.2	Tellurium Te 127.5	Iodine I 126.92	—
8	Xenon Xe 130.2	Caesium Cs 132.81	Barium Ba 137.37	Lanthanum La 139.0	Cerium Ce 140.25	—	—	—	—
9	—	—	—	—	—	—	—	—	—
10	—	—	—	Ytterbium Yb 172.0	—	Tantalum Ta 181.5	Tungsten W 184.0	—	Osmium, Iridium, Platinum Os Ir Pt 190.9, 193.1, 195.2
11	—	Gold Au 197.2	Mercury Hg 200.6	Thallium Tl 204.0	Lead Pb 207.2	Bismuth Bi 208.0	Polonium Po 210.0	—	—
12	Niton Nt 222.4	—	Radium Ra 226.0	Actinium Ac 226.0	Thorium Th 232.15	Brevium Bv 234.0	Uranium U 238.2	—	—
Maximum Valencies									
	R	R ₂ O	R ₂ O ₂	R ₂ O ₃	R ₂ O ₄	R ₂ O ₅	R ₂ O ₆	R ₂ O ₇	R ₂ O ₈

APPENDIX III

Periodic System of Notes.

	O	I	II	III	IV	V	VI	VII	VIII
I	C ₂	C ₁	C	c	c ¹	c ³	c ³	c ⁴	c ⁵
2	C ₂ [#]	C ₁ [#]	C [#]	c [#]	c ^{#1}	c ^{#2}	c ^{#3}	c ^{#4}	c ^{#5}
3	D ₂	D ₁	D	d	d ¹	d ²	d ³	d ⁴	d ⁵
4	D ₂ [#]	D ₁ [#]	D [#]	d [#]	d ^{#1}	d ^{#2}	d ^{#3}	d ^{#4}	d ^{#5}
5	E ₂	E ₁	E	e	e ¹	e ²	e ³	e ⁴	e ⁵
6	F ₂	F ₁	F	f	f ¹	f ²	f ³	f ⁴	f ⁵
7	F ₂ [#]	F ₁ [#]	F [#]	f [#]	f ^{#1}	f ^{#2}	f ^{#3}	f ^{#4}	f ^{#5}
8	G ₂	G ₁	G	g	g ¹	g ²	g ³	g ⁴	g ⁵
9	G ₂ [#]	G ₁ [#]	G [#]	g [#]	g ^{#1}	g ^{#2}	g ^{#3}	g ^{#4}	g ^{#5}
10	A ₂	A ₁	A	a	a ¹	a ²	a ³	a ⁴	a ⁵
11	Bb ₂	Bb ₁	Bb	bb	bb ¹	bb ²	bb ³	bb ⁴	bb ⁵
12	B ₂	B ₁	B	b	b ¹	b ²	b ³	b ⁴	b ⁵
	I	2	2 × 2	2 × 4	2 × 8	2 × 16	2 × 32	2 × 64	2 × 128
	R	R ₂ O	R ₂ O ₂	R ₂ O ₃	R ₂ O ₄	R ₂ O ₅	R ₂ O ₆	R ₂ O ₇	R ₂ O ₈

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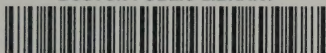
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